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I, CASSANDRA RICHARDS, ACTING TEAM LEADER EXAMINATION SUPPORT & SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PQ 3220 for a patent by SOLA INTERNATIONAL HOLDINGS LTD filed on 01 October 1999.

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Second day of November 2000

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PROVISIONAL SPECIFICATION

Invention Title: **Progressive Lens**

The invention is described in the following statement:

FHPMELC699274005.4

PROGRESSIVE LENS

The present invention relates to a progressive ophthalmic lens and in particular to a progressive ophthalmic lens exhibiting improved functionality and ease of adaptation, particularly for the first-time or part-time wearer, and taking into account wearer sensitivity to swim, and to a process for producing such lenses.

Numerous progressive lenses are known in the prior art. Progressive lenses have heretofore been designed on the basis that they have distance, near and intermediate viewing zones. The intermediate zone joins the near and distance zones in a cosmetically acceptable way, in the sense that no discontinuities in the lens should be visible to people observing the lens of the wearer. The design of the intermediate zone is based on a line called the "eye path" along which the optical power of the lens increases more or less uniformly.

However, prior art progressive lenses present the wearer with significant adaptation difficulties. For example, a wearer who utilises progressive lenses for reading purposes may generally be inconvenienced by the limited width of vision for near tasks. Similarly, new progressive spectacle wearers may be sensitive to swim and may be unable or unwilling to learn new head postures dictated by prior art progressive lenses.

It would be a significant advance in the art if the progressive lens could more closely relate to the requirements of the individual wearer and to the natural eye movements of a wearer in performing intermediate and near tasks in particular and thus make adaptation to a progressive prescription easier.

Accordingly, it is an object of the present invention to overcome, or at least alleviate, one or more of the difficulties and deficiencies related to the prior art. These and other objects and features of the present invention will be clear from the following disclosure.

Accordingly, in a first aspect of the present invention, there is provided a

progressive ophthalmic lens element including a lens surface having

an upper viewing zone having a surface power corresponding to distance vision,

a lower viewing zone having a greater surface power than the upper viewing zone to achieve a refracting power corresponding to near vision; and

an intermediate zone extending across the lens element having a surface power varying from that of the upper viewing zone to that of the lower viewing zone and including a corridor of relatively low surface astigmatism;

the lens surface including

a relatively high, relatively wide lower viewing zone; and

a relatively wide intermediate zone.

The present invention accordingly provides a progressive ophthalmic lens element exhibiting a balance in zone sizes which provides the wearer with significantly improved near and intermediate vision, thus making spectacles including the progressive ophthalmic lenses more acceptable to the first time or part-time wearer and making adaptation thereto a much simpler task.

In a preferred aspect the progressive lens design according to this aspect of the present invention may be such that the ratio of the area of clear vision of the upper (or distance) viewing zone to the lower (or near) viewing zone is less than approximately 3.50, preferably less than approximately 3.00.

This clear vision size ratio is indicative of effective relative zone sizes and illustrates the improved balance of zone sizes between the distance and near viewing zones in the ophthalmic lens elements according to the present invention. This is particularly advantageous for part-time wearers using the lenses mainly for reading.

The area of clear vision within each viewing zone may be defined by a limiting contour of RMS Power error equal to Add/4 (Diopters) inside a circle of 22 mm radius centred on a point 4 mm below the fitting cross, which will often coincide with the geometric centre of the lens.

By the term "Add" as used herein we mean surface addition power of the lens element.

In a further preferred aspect the progressive design lens according to this aspect of the present invention includes a surface design of the peripheral regions of the lens to reduce or minimise the phenomenon of "swim". By the term "swim" as used herein, we mean wearer perception of the unnatural movement of objects within the visual field during dynamic visual tasks, which may lead to a sense of unsteadiness, dizziness or nausea.

The applicants have found that the lens surface areas that are critical for reducing the swim sensation are within a pair of generally horizontally disposed opposed segments approximately ±45° above and below a generally horizontal axis passing through the fitting cross.

The opposed segments may have a radius of approximately 15 mm from the fitting cross, preferably approximately 20 mm, more preferably approximately 25 mm.

The minimisation of the swimming sensation may be achieved by reducing optical aberrations contributing to swim. These optical aberrations may take the form of the circumferential component of the ray traced prism gradient or, in terms of surface characteristics, the sagittal addition power within the opposed segments. Applicants have found that a reduction in maximum sagittal addition power down to less than 0.75*Add within the opposed segments may significantly reduce the phenomenon of swim for a wearer, in use.

This may have the result of increasing blur in the peripheral regions of the lower (or near) viewing zone. However, such blur increase in these regions is an acceptable trade-off in achieving wearer satisfaction with the progressive lenses.

In a still further preferred aspect of the present invention, the progressive lens design may exhibit a small amount of addition power (eg. 0.1 D to 0.4 D), proximate the fitting cross depending on the nominal addition power of the lens

element.

Applicants have found that the introduction of a small amount of addition power at the fitting cross aids the wearer in adapting to the progressive ophthalmic lens, particularly in respect of intermediate vision. The corridor of the intermediate viewing zone is thus effectively extended a small distance into the upper (or distance) viewing zone, allowing peripheral blur values to be reduced.

It will be understood that the ophthalmic lens element according to the present invention may form one of a series of lens elements.

The present invention accordingly relates to a progressive ophthalmic lens series exhibiting improved functionality and ease of adaptation, as it takes into account factors including one or more of the following: wearers' sensitivity to swim and natural eye movements. The progressive lens element within the series also exhibit a distance/near zone balance more appropriate for a part-time wearer than those provided by general purpose prior art progressive lenses.

Accordingly, in a further aspect of the present invention, there is provided a series of progressive ophthalmic lens elements, each lens element including a lens surface having

an upper viewing zone having a surface power to achieve a refracting power corresponding to distance vision;

a lower viewing zone having a greater surface power than the upper viewing zone to achieve a refracting power corresponding to near vision; and

an intermediate zone extending across the lens element having a surface power varying from that of the upper viewing zone to that of the lower viewing zone and including a corridor of relatively low surface astigmatism;

the progressive ophthalmic lens series including

lens elements having a base curve suitable for use in providing a range of distance prescriptions for emmetropes, each lens element differing in prescribed addition power and including a progressive design including

a relatively high, relatively wide lower viewing zone and

a relatively wide intermediate zone; the dimensions of the intermediate and

lower wearing zones being related to the prescribed addition power of the wearer.

As stated above, each progressive ophthalmic lens element according to the present invention exhibits a relatively high lower viewing, or near vision, zone. The relatively high lower viewing zone may reduce the need for the wearer to learn new head postures for reading purposes.

In a preferred embodiment of this aspect of the present invention, each lens element in the series may have a progressive lens design exhibiting a small amount of addition power proximate the fitting cross.

The addition power component proximate the fitting cross being related to the proscribed addition power and/or depth of focus of the wearer.

For example, for low to medium addition powers from approximately 1.0 D to 2.50 D, the relatively high, relatively wide lower viewing zone may permit useful reading from a point (the highest reading point) approximately 10 to 12 mm below the fitting cross. Thus the effective corridor length is approximately 10 to 12 mm.

For higher addition powers, eg. from approximately 2.50 D and above, the lower viewing zone may permit useful reading from a point (the highest reading point) approximately 12 mm below the fitting cross. Then the effective corridor length is approximately 12 mm. It will be understood that the slight increase in effective corridor length at higher addition powers permit an increased effective lower or near viewing zone size and/or lower peripheral blur.

By the term "highest reading point" we mean the highest point along the eye path where the wearer can read normal size text at the 40 cm reading distance without perceiving the blur. This is equal to the nominal prescribed add minus the effective depth of focus for near vision which is around 0.50 D for a broad range of addition powers.

The size of the lower viewing zone may be from approximately 20 to 60% larger in area on the lens surface than for the comparable prior art progressive

lenses.

These modifications in progressive lens designs within the series, may, for example, make the lens easier to adapt to, as the greater smoothing of the circumferential prism gradients over large areas of the peripheral zones lessens the uncomfortable swimming sensation that can be induced by a progressive lens.

Such modifications may provide the upper (distance) viewing zone with relatively high blur gradients. Whilst this may appear to be disadvantageous, the distance vision permitted remains quite reasonable, particularly at low to intermediate addition powers.

In a further preferred embodiment of this aspect of the present invention, the progressive lens design of each lens element in this series includes a surface correction to reduce or minimise the phenomenon of "swim".

The surface modification to reduce swim may be provided within a pair of generally horizontally disposed opposed segments generally centred at the fitting cross of each ophthalmic lens element. The opposed segments may extend approximately ±45° above and below a generally horizontal axis passing through the fitting cross.

The opposed segments may have a radius of approximately 15 mm from the fitting cross, preferably approximately 20 mm, more preferably approximately 25 mm.

The swim surface correction may be such as to reduce optical aberrations contributing to swim. The swim surface correction may take the form of a reduction in the circumferential component of the ray traced prism gradient, or, in terms of surface characteristics, the sagittal addition power inside the segments defined above.

Whilst this may have the result of increasing blur in the peripheral regions of the lower (or near) viewing zone, such blur increase in these regions is an

acceptable trade-off in achieving a greater wearer satisfaction with the progressive lenses.

As stated above, Applicants have found that a reduction in maximum sagittal addition power down to less than 0.75*Add within the opposed segments may significantly reduce the phenomenon of swim for a wearer, in use.

In a preferred embodiment of this aspect of the present invention, the progressive design of each lens element within the series exhibits a substantially constant ratio of the area of clear vision of the upper (or distance) viewing zone to the lower (or near) viewing zone for all addition powers. The clear vision size ratio may generally be less than approximately 3.50, preferably less than approximately 3.00.

The generally constant clear vision size ratio may thus provide the wearer with a generally constant quality of foveal vision independent of addition power.

In a further preferred embodiment of this aspect of the present invention, the progressive lens design of each lens element within the series exhibits a substantially constant area of clear vision on the lens surface within the lower viewing zone. Accordingly the progressive design of each lens element within the series provides the wearer with a generally constant, improved area of clear vision for near tasks across a range of addition powers.

By the term "corridor", we mean an area of the intermediate zone of varying power bounded by nasal and temporal contours of tolerable aberration for foveal vision.

The corridor has a "corridor length" (L), which corresponds to the length of the segment of the visual fixation locus which extends from the vertical height of the fitting cross (FC) to the vertical height of the near zone measurement point. For example, in a typical lens element according to the present invention, the power progression begins at the fitting cross (FC) height.

By the term "effective corridor length" as used herein we mean the length from the "fitting cross" (FC) to the highest reading point (HRP) on the lens surface.

By the term “lens element”, we mean all forms of individual refractive optical bodies employed in the ophthalmic arts, including, but not limited to,-lenses, lens wafers and semi-finished lens blanks requiring further finishing to a particular patient’s prescription. Also included are formers used in the manufacture of progressive glass lenses and moulds for the casting of progressive lenses in polymeric material such as the material sold under the trade designation CR39.

By the term “astigmatism or surface astigmatism”, we mean a measure of the degree to which the curvature of the lens varies among intersecting planes which are normal to the surface of the lens at a point on the surface.

The distribution of RMS power error may be varied proximate the peripheries of the upper (distance) and/or lower (near) viewing zones.

Preferably the distribution of RMS power error exhibits a relatively low gradient proximate the distance periphery and a relatively high gradient proximate the near periphery.

In a preferred aspect of the present invention, the location of the corridor of the ophthalmic lens element may be dictated at least in part by the visual fixation locus;

the visual fixation locus being inset generally horizontally nasally below the fitting cross (FC) of the lens element.

By the term "visual fixation locus", as used herein, we mean the set of points which are the intersection of the lens surface and the patient's line of sight as he or she fixates on objects in the median plane. The term does not signify a required, continuous eye movement path. Rather, the visual fixation locus indicates the set of points corresponding to variously positioned objects in the median plane.

As will be explained in detail below, the visual fixation locus takes into account the fact that the wearer may or may not use the accommodative reserve for a particular fixation. As a result, points at different locations in the visual fixation locus are provided having a power sufficient for comfortable use at the appropriate object distances.

The fitting cross (FC) is generally located at $(0,y_{FC})$. The value of y_{FC} may vary, for example, from approximately 2 mm to 6 mm above the geometric centre of the lens element.

The optical lens element may further include a relatively wide upper viewing zone with relatively low surface astigmatism at low addition powers. At medium to higher addition powers the upper viewing zone may exhibit slightly increased surface astigmatism.

Mathematical Description of Lens Surface

In a still further aspect of the present invention, there is provided a method of designing an ophthalmic lens element including a first lens surface having

an upper viewing zone having a surface power corresponding to distance vision,

a lower viewing zone having a greater surface power than the upper viewing zone to achieve a refracting power corresponding to near vision; and

an intermediate zone extending across the lens element having a surface power varying from that of the upper viewing zone to that of the lower viewing zone and including

a corridor of relatively low surface astigmatism; the ophthalmic lens element including

a relatively high, relatively wide lower viewing zone; and

a relatively wide intermediate zone,

which method includes

selecting a merit function relating to at least one optical characteristic of the lens to be minimised with an appropriate distribution of the optimisation weights on the lens surface; and

solving the global minimisation problem using the Finite Element Method; and

fabricating an ophthalmic lens element having a lens surface shaped according to said optimised surface description.

The ophthalmic lens element may be formulated from any suitable material. A polymeric material may be used. The polymeric material may be of any suitable type. The polymeric material may include a thermoplastic or thermoset material. A material of the diallyl glycol carbonate type, for example CR-39 (PPG Industries) may be used.

The polymeric article may be formed from cross-linkable polymeric casting compositions, for example as described in Applicants' United States Patent 4,912,155, United States Patent Application No. 07/781,392, Australian Patent Applications 50581/93, 50582/93, 81216/87, 74160/91 and European Patent Specification 453159A2, the entire disclosures of which are incorporated herein by reference.

The polymeric material may include a dye, preferably a photochromic dye, which may, for example, be added to the monomer formulation used to produce the polymeric material.

The ophthalmic lens element according to the present invention may further include standard additional coatings to the front or back surface, including electrochromic coatings.

The front lens surface may include an anti-reflective (AR) coating, for example of the type described in United States Patent 5,704,692 to Applicants, the entire disclosure of which is incorporated herein by reference.

The front lens surface may include an abrasion resistant coating. e.g. of the type described in United States Patent 4,954,591 to Applicants, the entire disclosure of which is incorporated herein by reference.

The front and back surfaces may further include one or more additions conventionally used in casting compositions such as inhibitors, dyes including thermochromic and photochromic dyes, e.g. as described above, polarising agents, UV stabilisers and materials capable of modifying refractive index.

The present invention will now be more fully described with reference to the accompanying figures and examples. It should be understood, however, that the description following is illustrative only and should not be taken in any way as a restriction on the generality of the invention described above.

In the figures:

Figure 1 illustrates contour plots of Surface Astigmatism of a series of optical lens elements according to the present invention, having various addition powers from 1.00 D to 2.75 D.

Figure 2 illustrates contour plots of Surface Mean Power of the optical lens elements according to Figure 1.

Figure 3 illustrates contour plots of optical RMS Power Error of the optical lens elements according to Figure 1. Ray tracing has been carried out with the model lens in the material with refractive index of 1.537 having the front surface as shown in Figures 1 and 2 with the base curve of 5.00 D, a spherical back surface of 4.95 D, zero prism at the prism reference point and centre thickness of 2 mm; located in the front of the eye at a 27 mm back vertex distance from the centre of rotation of the eye and tilted pantoscopically by 7 degs. The assumed object field of the ray trace has a vertically varying distance starting at infinity (the dioptric distance of 0.00 D for all rays crossing the front lens surface at elevations above the FC, through a linearly decreasing object distance below the FC up to the NMP, where the object distance was 0.4 m (2.5 D) for all adds up to 2.50 D, and staying constant along each ray at 0.4 m for elevations below the NMP. In the case of the 2.75 D add the near object distance was slightly shorter - 0.36 m (2.75 D). In calculating the mean power error of the ray traced image as perceived by the wearer it has been assumed that the wearer has up to (2.5 - Add) D of reserve

accommodation enabling him/her to cancel the negative mean power errors up to that magnitude in the lower part of the lens.

Figures 4 a and b illustrate RMS power error contour plots ray traced for distance objects (object distance of infinity) and near objects (object distance of 40 cm), respectively for a selection of optical lens elements from the series illustrated in Figure 1. (Addition Powers 1.50 D, 2.00 D and 2.50 D). The areas of clear vision are defined by a limiting contour of RMS power error equivalent to Add/4 (in Diopters) inside a circle of 22 mm radius centred on a point 4 mm below the fitting cross, which will often coincide with the geometric centre of the lens. Zones are coloured pale grey, their size is indicated in mm^2.

It will be understood that the invention disclosed and defined in this specification extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

It will also be understood that the term “comprises” (or its grammatical variants) as used in this specification is equivalent to the term “includes” and should not be taken as excluding the presence of other elements or features.

SOLA INTERNATIONAL HOLDINGS LTD
By their Registered Patent Attorneys
Freehills Patent Attorneys

5 October 1999

Figure 1

Surface Astigmatism of Lenses

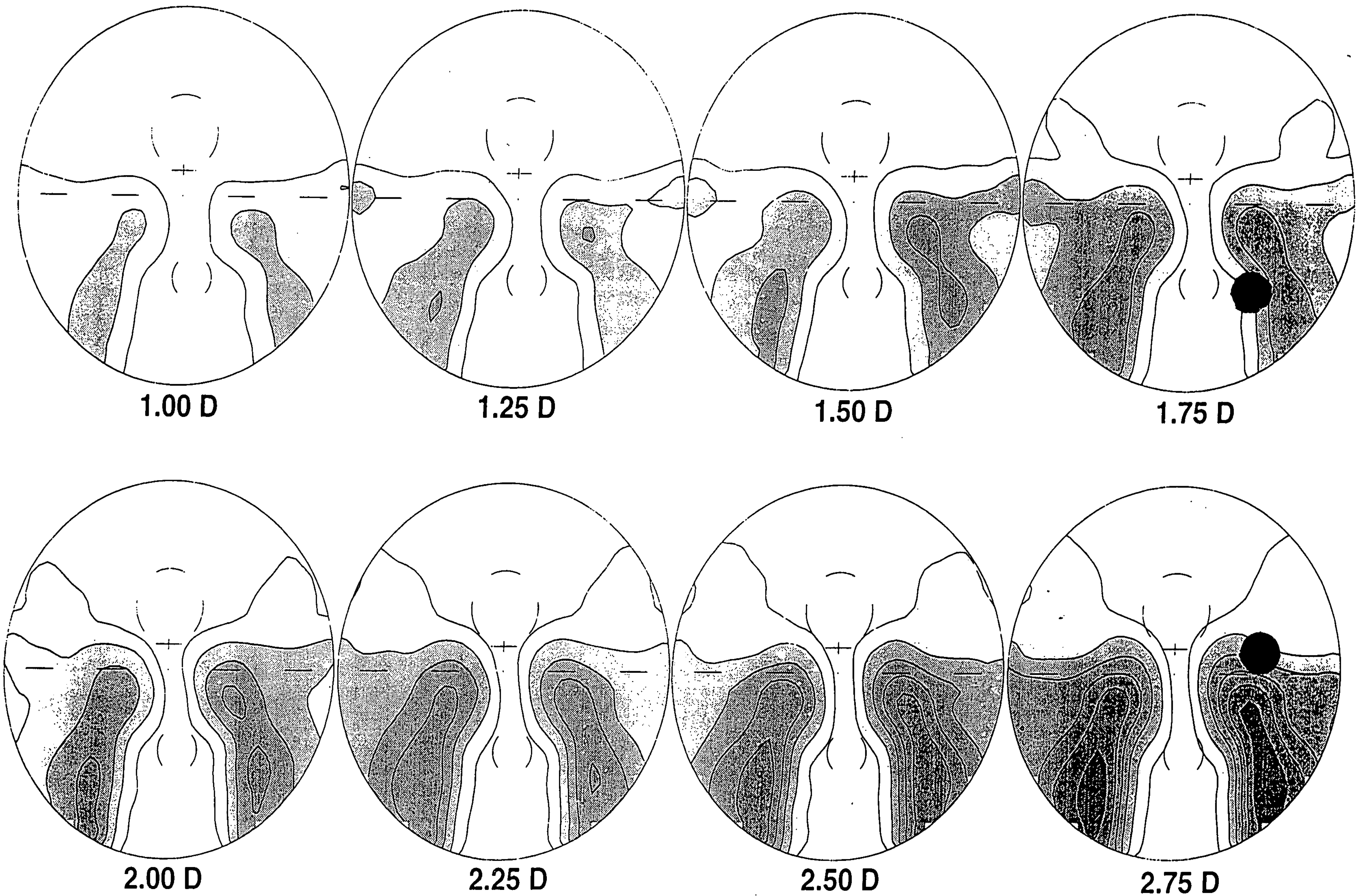


Figure 2

Surface Mean Power of Lenses

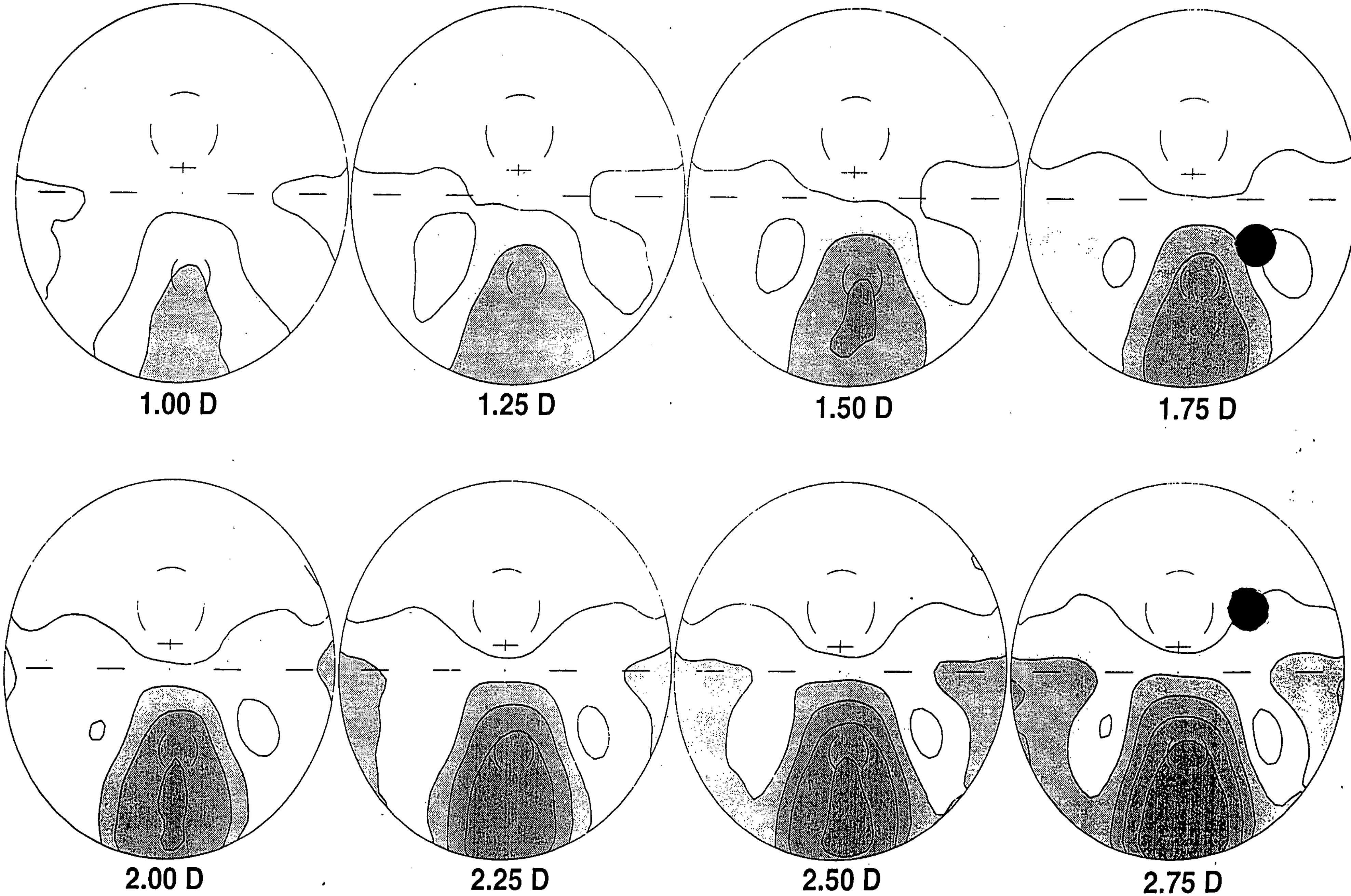
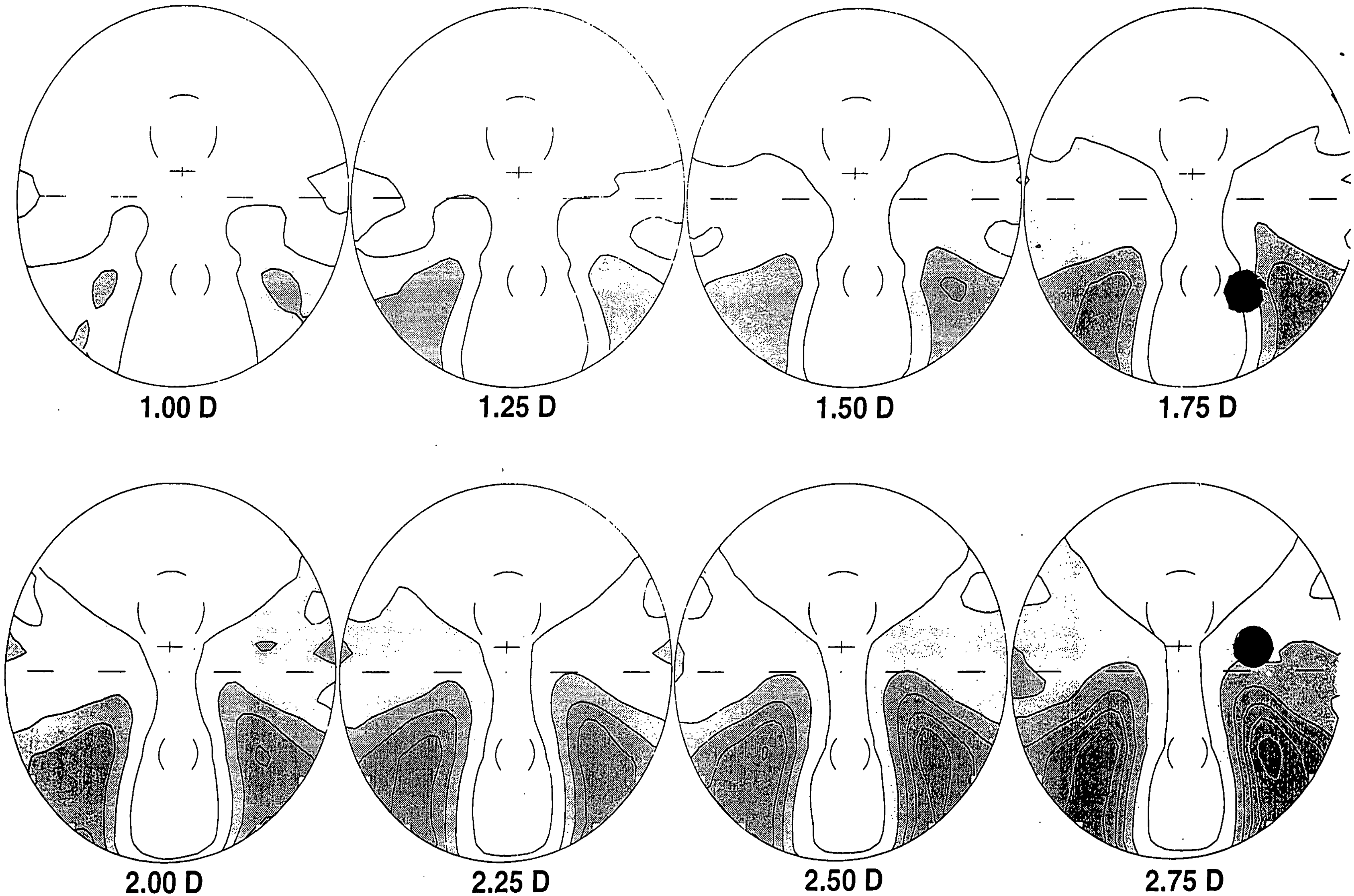


Figure 5

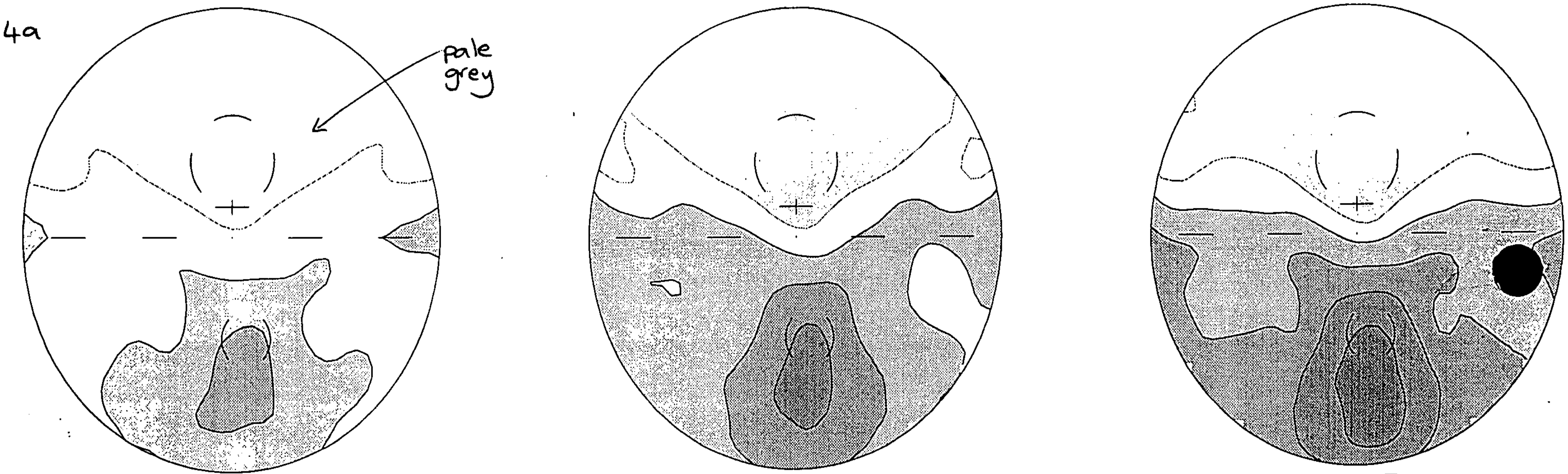
Optical RMS Power Error of Lenses



Clear Vision Zone Sizes
Distance Objects

Figure 4a

Zone area = 484.5 | Zone area = 467.6 | Zone area = 467.8

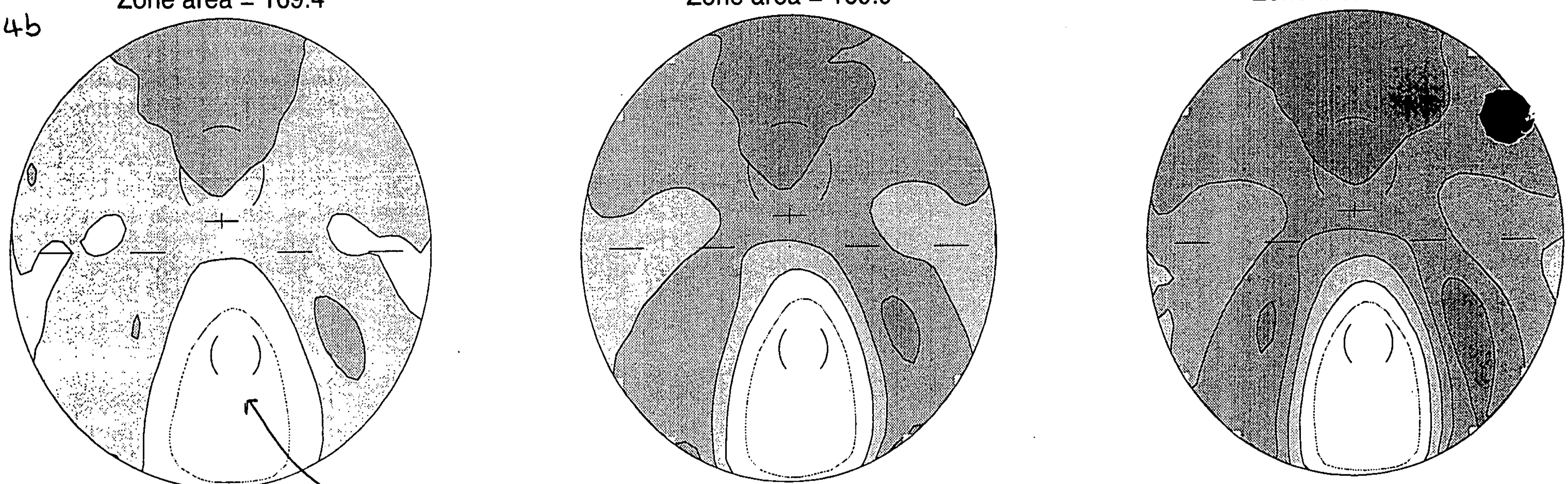


1.50 D | 2.00 D | 2.50 D

Near Objects

Figure 4b

Zone area = 169.4 | Zone area = 169.9 | Zone area = 153.6



1.50 D | 2.00 D | 2.50 D